Research Problem Review 79-5

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TACFIRE OT 056 HUMAN FACTORS EVALUATION

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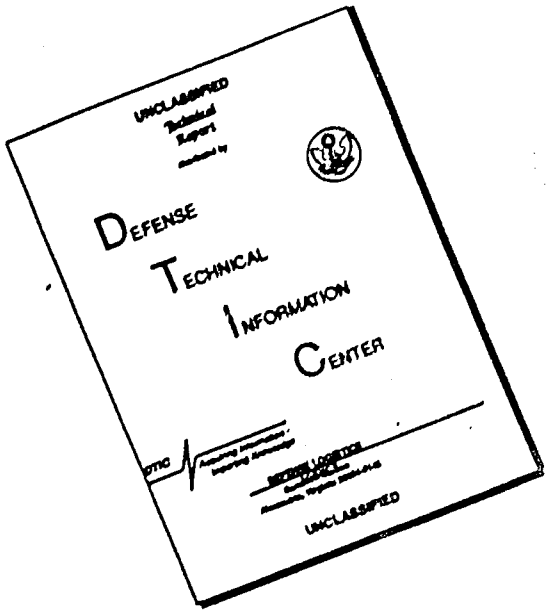

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Human Performance
in Field Assessment

Research Problem Review 79-5

(6) TACFIRE OT 056 HUMAN FACTORS EVALUATION

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(12) 88

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FOREWORD

As the equipment used by the armed forces becomes more complex, it places an increasingly greater demand on the individual soldier. To avoid overloading the mental and physical capabilities of the soldier, it is important to analyze new weapons systems to determine how the man-machine interfaces of such weapons can best be designed for optimal utilization by the human operator. Moreover, the impact of new systems on training requirements must be assessed. To this end, this human factors evaluation of the Tactical Fire Direction System (TACFIRE) for the field artillery was conducted in conjunction with TACFIRE OT 056. This research was done in response to a Human Resources Need sponsored by the TRADOC Combined Arms Test Activity (TCATA). This report supplements the TCATA TACFIRE OT 056 test report.

The entire project is responsive to special requirements of the Office of the Deputy Chief of Staff for personnel and to Army Project 2Q263743A775.

JOSEPH ZEIDNER
Technical Director

TACFIRE OT 056 HUMAN FACTORS EVALUATION

BRIEF

Requirement:

This research was conducted as a human factors evaluation of the Tactical Fire Direction System (TACFIRE) command and control system for the field artillery. This report supplements the TCATA OT 056 test report. It provides a human factors evaluation of equipment, tasks and operating procedures, training, and personnel selection requirements.

Procedure:

A variety of techniques were used in this human factors evaluation. Questionnaires were developed and administered; these addressed specific human factors issues. These questionnaires were supplemented by interviews and by pertinent data from TCATA questionnaires and data collection forms. Performance assessments were also obtained for individual operators at the Artillery Control Console and on the Digital Message Device. Personnel records and formal course grades were used to analyze personnel selection requirements.

Findings:

The battalion S-280 shelter is regarded as unacceptable by battalion Fire Direction Center personnel. The major problem areas are the shortage of space within the shelter, the configuration of equipment within this limited space, the quality of the air, and the noise level. Noise levels are in excess of MIL-STD-1474A.

With the exception of the Digital Message Device and the Digital Plotter Map, there is widespread acceptance of individual TACFIRE equipments.

Although operators maintain that their tasks, on the average, are easy, the consensus of operators is that TACFIRE training must be conducted frequently if skills are to be maintained. Estimates of time required to train averaged about 2 days a week at the computer Fire Direction Center and Variable Format Message Entry Device sites and 1 day a week at Digital Message Device sites. Moreover, indications are that more emphasis needs to be placed on maintenance training.

Operators who use the standard (QWERTY) keyboard should know how to type. The Army Classification Battery appears to provide a cost-effective means of selecting individuals for TACFIRE schooling.

Utilization of Findings:

The findings of this report will serve as the human factors input to TCATA and OTEA for their evaluation of the TACFIRE system. These findings will also be sent to the Army Field Artillery School (USAFAS) for their impact on training and personnel selection requirements.

TACFIRE OT 056 HUMAN FACTORS EVALUATION

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TACFIRE OT 056 HUMAN FACTORS EVALUATION

INTRODUCTION

The Tactical Fire Direction System (TACFIRE) was developed to automate the command and control function for the field artillery. The system consists of computers, which are located at the division artillery (DivArty) and battalion fire direction centers, and various remote terminals, which the S3s, FSOs, FOs, FSE, and firing batteries use to interface with the computers.

The DivArty Fire Direction Center (FDC) is housed in two S-280 shelters. Battalion FDCs are housed in one S-280 shelter. Key equipment within the FDCs are the Artillery Control Console (ACC), the Electronic Line Printer (ELP), the Digital Plotter Map (DPM), and the Central Communications Unit (CCU). Key personnel are the Fire Direction Officer (FDO), the Artillery Control Console Operator (ACCO), and the TACFIRE Equipment Specialist, who is usually responsible for operating the CCU.

The S3s, FSOs, and FSE use the variable format message entry device (VFMED), a remote terminal, to interface with the TACFIRE system. FOs use the digital message device to interface with TACFIRE. The VFMED and the DMD are two-way devices, whereas the Battery Display Unit, used at the firing batteries, can only receive messages.

OBJECTIVES

The Human Factors evaluation was undertaken in conjunction with TACFIRE OT 056 for the following objectives:

1. To assess player evaluations of key TACFIRE equipments.

2. To assess player evaluations of tasks and operating procedures.

3. To evaluate the training of selected personnel and to estimate future training requirements.

4. To provide an initial assessment of personnel selection requirements.

METHOD

Questionnaires and Interviews

The primary assessment tool was the questionnaire. Questionnaires were designed to assess each of the four areas of analysis. Questionnaires came from two sources, TRADOC Combined Arms Test Activity (TCATA) and the Army Research Institute for the Behavioral and Social Sciences (ARI). The TCATA questionnaires were developed to address specific data requirements as required by the Test Design Plan. The ARI questionnaires (see Appendix A) were developed to address specific human factors issues. The following questionnaires were designed: Personnel Data Form; Operator's Questionnaire; Workload; Team Performance; Safety Questionnaire; Shelter Environment Questionnaire; and questionnaires on the Artillery Control Console, Digital Plotter Map (DPM), Electronic Line Printer (ELP), Communications Control Unit (CCU), Variable Format Message Entry Device (VFMED), and Digital Message Device (DMD). These questionnaires were then assembled into questionnaire packets. The Fire Direction Center (FDC) packets included all questionnaires except the VFMED and DMD questionnaires. The FDC packets were administered to FDC personnel at both the battalion and DivArty FDCs. The VFMED packets consisted of the Personnel Data Form, and the Operator, Safety, VFMED, and ELP questionnaires. VFMED packets were administered to player personnel at VFMED sites--the Fire Support Element, the FSOs, and the Operations and Intelligence Elements. The DMD packets consisted of the same forms as the VFMED packets, except the DMD questionnaire was substituted for the VFMED questionnaire and the ELP questionnaire was not included. The DMD packets were administered to Forward Observer Teams, Target Acquisition Personnel, and the Air Observers. In short, the questionnaires for specific equipments were administered to appropriate individuals.

The questionnaires were tabulated to present the data in the most meaningful way. Data were considered by both individual positions and units, but the most meaningful way to present the data, with one exception, was by the questionnaire packets--FDC, VFMED, and DMD. The exception was the Shelter Environment Questionnaire, which was considered at DivArty and battalion levels separately. The different equipment configurations at the two levels had pronounced implications.

The questionnaire data were supplemented with interviews. Interviews were conducted when necessary to clarify ambiguities in questionnaire responses or to resolve issues. Interviews were also conducted when small sample size precluded meaningful quantification of questionnaire results.

Individual Operator Performance Assessments. Two formal assessments were taken of individual operator proficiency. One assessment, conducted by the New Equipment Training Team from USAFAS, was taken after operators had completed the initial DMD training course. Operators were required to process five missions typically encountered by

forward observers. The criterion was the length of time it took to process the five missions correctly. This assessment provided an estimate of the individual operator's proficiency after completion of initial training.

The second assessment[1] was a formal experiment, also conducted with the assistance of the New Equipment Training Team, which examined the proficiency of FDC personnel at the ACC as a function of training time on the system. This assessment was taken in mid-November 1977. Operators were required to process 10 requirements commonly encountered at the ACC. All requirements were scored for accuracy, and eight of the requirements were timed.

Ancillary Sources of Assessment. Other data sources were used to supplement the human factors analysis. Observations from data collector/controllers were included when pertinent. Onsite observations were made of operations and maintenance actions. An audiologist from the Hearing Conservation Section of the Health and Environment Activity, U.S. Army medical department activity (MEDDAC), provided an assessment of potential system hearing hazards (see Appendix B). In short, any relevant data were considered.

RESULTS

Player Evaluations of Equipments and Shelters

DivArty S-280 Shelters. Because of the small sample size (N = 4), the responses of DivArty FDC personnel on the DivArty Shelter Environment Questionnaire are not summarized in tabular form. The responses provided were generally positive. No negative responses were given (e.g., "Unacceptable" or "Very Unacceptable"). "Borderline" responses, however, were given on several items; these items were numbers 3 (temperature control system, one response), 4 (air quality, two responses), 5 (workspace, one response), 6 (storage space, two responses), 7 (working surface, one response), 9 (noise level, three responses), 11 (chairs, one response), and 12 (working conditions, one response).

One Fire Direction Officer (FDO) expressed dissatisfaction with the physical layout of equipments within the shelter and offered the following suggestions: (a) Position the ACC so that the FDO can stand on the left of the ACCO. With this arrangement, the FDO can operate the switch panel assembly during peak periods while the ACCO operates the keyboard. (b) Position RCMUs so that they can be operated at the

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[1] Griffith, D., Degree of Training and Artillery Control Console Operator (ACCO) Proficiency. ARI Research Problem Review 79-3, February 1979.

ACC without standing up. (c) Position DPM controls so that they can be operated without walking across the shelter.

Other respondents suggested that the shelter environment should have a temperature control system and that the equipment should be less bulky.

Battalion S-280 Shelter. Table 1 summarizes results of the Battalion Shelter Environment Questionnaire. In contrast to those for the DivArty FDC shelters, evaluations of the battalion FDC shelters were decidedly negative. The primary problem of the battalion shelter is space; 62% of the respondents regarded the workspace in the shelter as clearly unacceptable, whereas only 8% regarded the workspace as acceptable (see item 5). Similarly, the storage space provided was rated as acceptable by only 33% of the respondents (see item 6). Item 7 indicated that only 52% of the respondents regarded the working surface as acceptable. The shortage of space was further complicated by the configuration of the equipments within the available space. Two suggestions were offered for moving the CCU. One suggestion was to move the CCU next to the ACC (to the left of the ACCU). The reason for this suggestion is discussed under team performance. Basically, this arrangement would allow the CCUO and the ACCO to help each other more readily. The other suggestion was to interchange the CCU with the DPM. The rationale for this arrangement was to permit the CCUO greater access to the outside of the shelter to check communications lines, generator, etc. Other suggestions for solving the space problem included placing the FDC into a large van or placing the FDC and the O&I VFMED into two 5-ton shelters. The space problem is seen as critical by most FDC personnel. One respondent said that having more space would solve 90% of the problems in the FDC. This problem adversely affects both operational performance and maintenance. Moreover, sustaining operations is difficult when maintenance is being performed in the battalion shelter.

After the problem of space, the next most serious human factors problem is noise level. The audiologist's report (see Appendix B) indicated that the noise level exceeded MIL-STD-1474A. This noise problem is aggravated further by the digital and voice traffic in the shelters. Moreover, only 37% of the respondents regarded the noise level in the shelter as acceptable. The impact of the noise level was so great that fewer than half the respondents thought spoken communications within the shelter were easy to understand.

A third human factors problem within the shelter is air quality. Only 41% of the respondents regarded the quality of air as acceptable. One source of this problem was the ELP, which emitted an unpleasant odor when copying. Cigarette smoking inside the shelter further aggravated the air quality. Finally, there were several incidents in which personnel became sick in the shelter. Under certain conditions, carbon

Table 1

Summary of Responses for the Shelter Environment Questionnaire (Battalion)

1. Overall, the shelter environment was (N = 25)

A	B	C	D	E
Very Comfortable	Comfortable	Borderline	Uncomfortable	Very Uncomfortable
4%	16%	36%	20%	24%

2. Typically, the temperature in the shelter was (N = 25)

A	B	C	D	E
Much Too Hot	Too Hot	About Right	Too Cold	Much Too Cold
4%	12%	56%	24%	4%

3. The temperature control system in the shelter was (N = 24)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
12%	42%	25%	17%	4%

4. The quality of the air was (N = 24)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
8%	33%	29%	12%	17%

5. The workspace provided in the shelter was (N = 24)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
0%	8%	29%	29%	33%

Table 1 (Continued)

6. The storage space provided was (N = 24)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
0%	33%	21%	29%	17%

7. The working surface was (N = 23)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
0%	52%	17%	13%	17%

8. The level of illumination in the shelter was (N = 24)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
50%	46%	4%	0%	0%

9. The noise level in the shelter was (N = 24)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
4%	33%	25%	25%	12%

10. Spoken communications within the shelter were (N = 24)

A	B	C	D	E
Very Easy to Understand	Easy to Understand	Borderline	Difficult to Understand	Very Difficult to Understand
0%	46%	37%	25%	0%

Table 1 (Continued)

11. The chairs were (N = 23)

A	B	C	D	E
Very Comfortable	Comfortable	Borderline	Uncomfortable	Very Uncomfortable
0%	78%	17%	4%	0%

12. Working conditions inside the shelter were (N = 24)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
0%	33%	46%	17%	4%

13. Working conditions inside and outside the shelter were (N = 23)

A	B	C	D	E
Very Safe	Safe	Borderline	Dangerous	Very Dangerous
0%	83%	13%	4%	0%

monoxide apparently was drawn in through the air conditioner. This problem is reported in detail elsewhere.[2]

The most serious safety consideration also concerned the quality of air in the shelter. Respondents complained that the air conditioner drew in exhaust fumes from the truck. The obvious solution to this problem would be to reposition the truck's exhaust; however, the problem appears to be more complicated. A number of FDC personnel became sick in the shelter prior to OT III testing, and these incidents led to the detailed study by the Health and Environment Activity, USA MEDDAC.

Several other safety problems were mentioned. The ladder on the S-280 shelter has steep steps and no handrail. Conditions are especially treacherous at night or during inclement weather. Incidents of persons falling off the ladder were reported during the test. A related concern was expressed regarding the support arms on the rear dock. Some respondents thought that the metal support arms were too lightweight (weak) to support people standing on the rear dock. Some respondents thought that the weight distribution in the shelter caused the vehicle to lean to the left, increasing the risk that the vehicle might topple over. It was also suggested that safety chains be attached to the air conditioning unit to anchor the unit during travel over rough terrain.

Artillery Control Console (ACC). A brief study of the responses to the ACC questionnaire (see Table 2) indicated full acceptance of the ACC--the overall acceptance rate for the ACC is 100% (see item 1). Item 9 (troubleshooting) is the only item for which the acceptance rate falls below 70%. Because the operators receive a limited amount of maintenance training, there is some question regarding the extent to which this problem is one of maintainability design or one of training deficiency.

Other comments regarding the ACC are related to the problems of space and equipment configuration within the battalion shelter. For example, the FDO has difficulty viewing the receive display and the compose/edit display. As a result, the FDO must either put his complete faith in the ACCO or rely upon ELP printouts. The latter option can result in confusion because the messages on the receive display can lag several minutes behind the current output on the ELP.

Digital Plotter Map (DPM). Table 3 indicates that the DPM was evaluated more negatively than most other TACFIRE equipments that were individually evaluated. Item 1 indicates that the overall acceptance rate of the DPM was less than 70%. Comments regarding the DPM

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[2]Results of an Investigation: Possible Toxic Gas Exposure in a Computer Shelter (TACFIRE). Health and Environment Activity, USA MEDDAC, 23 February 1978.

Table 2

Summary of Responses to the Artillery Control Console Questionnaire

1. The overall performance of the ACC was (N = 27)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
30%	70%	0%	0%	0%

2. The design of the keyboard on the ACC was (N = 27)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
22%	78%	0%	0%	0%

3. The design of the controls on the ACC was (N = 27)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
11%	89%	0%	0%	0%

4. The design of the receive display editor was (N = 27)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
18%	74%	4%	4%	0%

5. The design of the compose/edit display editor was (N = 27)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
18%	70%	7%	4%	0%

Table 2 (Continued)

6. The design of the ACC for ease of message composition was (N = 27)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
22%	70%	7%	0%	0%

7. The design of the ACC for ease of message correction was (N = 26)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
15%	73%	8%	4%	0%

8. The design of the ACC for ease of reviewing messages was (N = 27)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
22%	74%	0%	4%	0%

9. Troubleshooting the ACC was (N = 25)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
16%	52%	28%	4%	0%

Table 3

Summary of Responses for the Digital Plotter Map Questionnaire

1. Overall, the performance of the DPM was (N = 28)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
7%	61%	28%	4%	0%

2. The design of the controls on the DPM was (N = 28)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
7%	86%	7%	0%	0%

3. The DPM was (N = 28)

A	B	C	D	E
Highly Legible	Legible	Borderline	Illegible	Highly Illegible
11%	54%	36%	0%	0%

4. Troubleshooting the DPM was (N = 26)

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult
8%	38%	31%	23%	0%

indicated dissatisfaction with the amount of time it took to make plots and with the travel locks on the DPM. As one respondent put it, "Reposition the two travel locks on the DPM to facilitate installation/removal by someone other than a 90-pound woman with size 4 hands."

Item 3 indicates that fewer than 70% of the respondents regarded the DPM as legible. Some respondents thought the printing was too large. One respondent remarked that when there was more than one unit in the same grid square, it was impossible to read the printing because it overprinted itself. Comments also indicated that the pen tended to dry up quickly.

The biggest problem regarding the DPM concerns maintenance. Item 4 in Table 3 shows that 46% of the respondents regarded troubleshooting as easy or very easy. This result is probably attributable to both the maintainability design of the equipment and to a deficiency in maintenance training. A related problem is that when the DPM was pulled out to perform maintenance, operations within the battalion FDC were greatly hampered.

Electronic Line Printer (ELP). Table 4 reveals a general acceptance of the ELP. However, two of the five items indicate possible problem areas. Item 3 shows a less than 70% acceptance rate regarding the design of the ELP for ease of reviewing messages. Some respondents complained of having to advance the paper to read the printouts.

A second possible problem concerns maintenance (see item 5). As with other equipment, the extent to which this problem is one of maintainability design or one of operator maintenance training remains to be determined.

Other comments regarding the ELP included the following: "The smell and dust are very offensive and dangerous to humans." "Top was permanently removed and stored. The cover would often hang up paper." "Automatic paper advance worked infrequently." ". . . jammed too easily." "The ELP is too noisy."

Variable Format Message Entry Device (VFMED). Table 5 summarizes responses to the VFMED questionnaire. These results indicate that the VFMED is generally acceptable to its users. Although operators regarded the VFMED as acceptable, they suggested several improvements.

Some operators said the keyboard's positioning was too high. VFMED operators frequently unscrewed the keyboard, let it hang down, and propped it against a CVC helmet or some other convenient prop. This arrangement allowed the operator to lay the message to be typed above the keyboard and also facilitated typing on the keyboard. To rectify this situation, some operators suggested either an adjustable stool or an adjustable keyboard.

Table 4

Summary of Responses to the Electronic Line Printer Questionnaire

1. Overall, the performance of the ELP was (N = 65)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
17%	65%	15%	3%	0%

2. The design of the controls on the ELP was (N = 65)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
28%	71%	1%	0%	0%

3. The design of the ELP for ease of reviewing messages was (N = 65)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
20%	48%	21%	6%	5%

4. The ELP printouts were (N = 65)

A	B	C	D	E
Highly Legible	Legible	Borderline	Illegible	Highly Illegible
20%	68%	12%	0%	0%

5. Troubleshooting the ELP was (N = 64)

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult
8%	58%	22%	11%	1%

Table 5

Summary of Responses to the VFMED Questionnaire

1. Compared to the transmission of messages using a radio, the entry and transmission of messages with the VFMED was (N = 38)

A	B	C	D	E
Much Better	Better	The Same	Worse	Much Worse
34%	45%	8%	13%	0%

2. As my means of interfacing with the TACFIRE system, the VFMED was (N = 37)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
41%	57%	3%	0%	0%

3. The design of the keyboard on the VFMED was (N = 38)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
32%	47%	13%	7%	0%

4. The design of the display on the VFMED was (N = 37)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
32%	57%	5%	5%	0%

5. The design of the controls on the VFMED was (N = 37)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
32%	59%	8%	0%	0%

Table 5 (Continued)

6. Troubleshooting the VFMED was (N = 36)

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult
3%	47%	36%	14%	0%

7. The design of the VFMED for ease of message composition was (N = 37)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
19%	65%	13%	3%	0%

8. The design of the VFMED for ease of message correction was (N = 37)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
30%	67%	3%	0%	0%

9. The design of the VFMED for ease of reviewing messages was (N = 37)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

Another suggestion was to provide the VFMED with a smaller version of the matrix the ACC has for frequently used formats. Currently the VFMED operator must request formats from the FDC computer. However, the frequent delays keep the operator from accomplishing his task and also frustrate him. These delays prove particularly deleterious to fire planning. In short, some capacity for obtaining frequently used formats is highly desirable.

Troubleshooting is the biggest source of difficulty for the VFMED operator; only 50% of the operators regarded troubleshooting as easy or very easy (see item 6). Because maintenance training provided to VFMED operators is minimal, and because little or no maintenance equipment is available at VFMED sites, it cannot be determined from available data whether the problem is due to maintainability design, lack of training, or lack of maintenance equipment.

The primary safety concern at the VFMED site was the VFMED keyboard. When the keyboard was mounted in the M577, personnel complained of hitting their heads on the corner of the keyboard. Suggested improvements were to round off the edges and to make the keyboard flush with the machine. One person suggested moving the VFMED to the front of the cargo area.

Communications Control Unit (CCU). Table 6 provides a summary of the responses to the Communications Control Unit (CCU) questionnaire. On the whole, this equipment is rated as acceptable. Only item 3 (troubleshooting) revealed an acceptance rate of less than 70%. Again, interpretation depends on the extent to which the problem is due to maintainability design or operator maintenance training.

One suggestion offered for improving the CCU was to add the capacity to vary the volume of individual nets. When monitoring nets, the operator must increase the volume to hear the weaker signals. When a strong station transmits, however, the louder volume hurts the ears.

Digital Message Device (DMD). Table 7 shows responses for the DMD questionnaire. A review of these results yields somewhat equivocal impressions. Although a majority of the respondents (58%) regarded the DMD to be an improvement over the current means of transmission (see item 1), only 63% of the respondents regarded the DMD as an acceptable means of interfacing with the TACFIRE system (see item 2). Much of the overall dissatisfaction is probably attributable to problems in communications and in communications training.

The most frequently stated complaint regarding the DMD--its noise--was apparently in part a training problem. The DMD cables were connected improperly, which meant that to send a clear digital signal the volume had to be turned up so high that the noise was psychologically uncomfortable. Noise levels for the DMD are presented in Appendix B. The problem of aural nondetectability should be investigated.

Table 6

Summary of Responses to the Central Communications Unit Questionnaire

1. Overall, the performance of the CCU was (N = 28)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
21%	68%	11%	0%	0%

2. The design of the controls on the CCU was (N = 28)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
21%	61%	11%	7%	0%

3. Troubleshooting the CCU was (N = 22)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
0%	64%	23%	14%	0%

Table 7

Summary of Responses for the Digital Message Device Questionnaire

1. Compared to the transmission of messages using a radio, the entry and transmission of messages with a DMD was (N = 77)

A	B	C	D	E
Much Better	Better	The Same	Worse	Much Worse
19%	39%	5%	26%	10%

2. As the Forward Observer's means of interfacing with the TACFIRE system, the DMD was (N = 73)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
4%	59%	23%	11%	3%

3. The design of the keyboard on the DMD was (N = 76)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
14%	59%	17%	7%	3%

4. The design of the display on the DMD was (N = 76)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
17%	60%	12%	8%	3%

5. The design of the controls on the DMD was (N = 76)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
16%	70%	13%	1%	0%

Table 7 (Continued)

6. Battery replacement was (N = 77)

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult
18%	41%	26%	10%	4%

7. Troubleshooting the DMD was (N = 77)

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult
10%	51%	19%	16%	1%

8. The design of the DMD for ease of message composition was (N = 73)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
21%	57%	20%	3%	0%

9. The design of the DMD for ease of message correction was (N = 76)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
17%	70%	10%	3%	0%

10. The design of the DMD for ease of reviewing messages was (N = 76)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
30%	63%	4%	1%	1%

Table 7 (Continued)

11. The design of the DMD for night operation was (N = 75)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
41%	51%	7%	1%	0%

12. The design of the DMD for acknowledging ACK/NAK was (N = 76)

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable
24%	50%	17%	7%	3%

A second problem concerned the power source: Respondents indicated that the batteries were short-lived and hard to replace. However, when respondents used an external power source, they complained that the cables were too short. It was suggested that a flap be placed on the DMD case so that the battery could be changed without removing the unit from the case. Respondents also mentioned problems in having the batteries recharged.

Respondents commented that it was difficult to enter messages with the DMD while in a moving vehicle. Operators usually preferred to send messages by voice when in a moving vehicle.

Individuals who could type often commented that the alphabetical arrangement of the keyboard caused difficulty and that the standard QWERTY arrangement would facilitate message processing. Additional comments were that it was difficult to see the display in sunlight and that the DMD was too bulky.

Concern remains regarding the use of the DMD by air observers. One air observer claimed that the "message-received" sound emitted by the DMD cannot be heard in a helicopter. Consequently this air observer kept his head down so he could monitor the message light. When he did this, however, he experienced vertigo and air sickness. He also said that he could not navigate when he was using the DMD.

Player Evaluations of Tasks, Operating Procedures, and Organization

Battalion and DivArty Fire Direction Centers. Most personnel at the battalion and DivArty FDCs perceived their tasks as being easy. The following responses were received for "On the average the tasks required of me on operating the TACFIRE equipment were."

A	B	C	D	E	N
Very Easy	Easy	Borderline	Difficult	Very Difficult	
21%	61%	11%	7%	0%	28

Maintenance troubleshooting and communications were the two tasks that caused personnel the most difficulty. Other difficulties included "getting set up after a move," "remembering formats," "fire planning and ATI files," "peak period FM processing."

When asked which tasks should be modified and how they should be modified, respondents suggested equipment modifications (e.g., crank-up antennas, more compact, lighter weight equipment) and shelter reconfigurations (e.g., moving the MTS to the rear of the shelter, moving the CCU next to the ACC) rather than task modifications. Task modifications that were mentioned included the following: "Simplify FM," "Automatically enter AUF in an MTO," "RFAFs from observer radars should

automatically be accepted by the computer," and "MOI should not be sent repeatedly to subscribers who have already acknowledged the message."

Similarly, when asked for suggestions to improve their performance as operators, respondents made a number of suggestions about the reconfiguration/redesign of the shelter. Suggestions that did not fall into this category included the following: "Teach me to type"; "Provide a system addition which would allow the FDO to get an immediate mission status, e.g., a button on the ACC which would print active mission target numbers on the ELP"; "Allow FDO to edit a FM by target number or grid to show its status"; "Get messages that will make me think instead of just automatically knowing what to do"; "Have some sort of test on equipment operations against other battalions every two months or so."

Operators were also asked to estimate the percentage of time technical manuals or other reference materials had to be consulted. Median estimates by operator position were 20% for the ACCO, 15% for the FDO, and 10% for the CCUO. Maintenance was one of the most common tasks mentioned by all positions for which TMs and reference materials were used. Other tasks included the following: legal entries or required entries on formats, NNFP, FM and SYS programs, different key functions of CCU or the numbers of subscribers per net, and Survey and ATI.

FDC personnel were also asked about their respective workloads. When asked to estimate the percentage of time that their workloads became so heavy that their performance suffered, median estimates were 17.5% (FDO), 10% (ACCO), and 10% (CCUO). When asked when their workloads become overly heavy, comments were: "When there was a loss of communications or when communications were poor"; "During peak scenario periods" (DivArty); "During heavy volumes of fire missions when there were system breakdowns"; "When there were numerous voice missions"; "When physically fatigued at the end of shifts after sleep had been interrupted by a move"; "When FSOs were fireplanning in conjunction with other activities"; and "During CONOPs."

FDC personnel were also asked to estimate the percentage of time that their workloads were so light that they could have helped other members of the crew; median estimates were 20% (FDO), 30% (ACCO), and 25% (CCUO). When asked for specific times when they could have helped other team members, responses were: "When communications were good"; "When the mission was reinforcing" (GS battalion); "During the early morning hours"; "When there were less than 30 missions per hour"; "During normal operations the FDO can operate the ACC" (comment made by ACCO).

With respect to operator workload, FDC personnel were asked to provide recommendations for redistributing the workload to achieve more efficiency. Since these recommendations tended to entail equipment modification (most commonly they were some variant of "give us

more space"), they will be discussed with the Team Performance results.

On the Team Performance Questionnaire, FDC personnel were asked, "What modifications, if any, in the design of the equipment would improve the teamwork of the crew?" The most common response here was "Give us more space." Although several solutions were offered, they took two basic forms. One solution was to place the battalion FDC in a large van. A second solution was to provide another 5-ton truck and either to distribute the FDC between the two shelters as at DivArty or to use the second 5-ton truck to house the O&I VFMED as well as nonessential equipment from the FDC. Variants of this latter solution were either to provide an additional DPM to O&I or to remove the DPM from the FDC and place it with the O&I VFMED.

There were also suggestions to reconfigure the equipment. One suggestion was to move the CCUO next to the ACCO. This arrangement would allow the two operators to help each other more readily (in the battalion shelters, these two operators have their backs to each other). At DivArty, one FDO suggested that the ACC be positioned so that the FDO could be on the ACCO's left. This arrangement would allow the FDO to assist the ACCO much as the CCUO would be able to assist the ACCO at battalion.

Other suggested modifications included the following: "Provide more legroom for the ACCO," "Replace the FDO's folding chair with a smaller stool and backrest," "Permanently mount crank up 292 antenna," "Place a permanently mounted ramp on the back of the TACFIRE van," "Make the equipment less bulky," "Place a protector around the AC main power switch to prevent the power from being turned off accidentally," "Move the RD and CED scopes on the ACC so that they are more visible to the FDO."

FDC personnel were also requested to suggest any modifications in operating procedures for improving the teamwork of the crew. Some of these recommendations were the same as those provided above; e.g., reconfigure the equipment so that the CCUO and ACCO will be able to assist each other more readily. Other recommendations entailed modifications in the TO&E; e.g., providing two extra 5-ton drivers and at least one generator mechanic or providing enough personnel to operate three 8-hour shifts a day.

It was also suggested that smoking be forbidden in the shelter and that a cover be provided over the Power Converter Group toggle switches to prevent the switches from being accidentally turned off.

Finally, it should be noted that 12-hour shifts are regarded as excessive by most FDC personnel. The combined problems of crowding, noise, and air quality within the shelter, together with the cognitive demands of their jobs, take their toll. Subjective comments indicated that performance deteriorates well before a 12-hour shift is over. It

would be useful to assess experimentally the decline of operator performance as a function of time on task.

VFMED Sites. Personnel who interfaced with TACFIRE at the VFMED tended to regard their tasks as easy. The following responses were received for "On the average the tasks required of me in operating the TACFIRE equipment were."

A Very Easy	B Easy	C Borderline	D Difficult	E Very Difficult	N
8%	68%	24%	0%	0%	37

Personnel were asked to list the tasks which caused them the most difficulty. The most common response was fire planning; the problem seemed to be the time it took to get information back from the computer. The delays frustrated the operators. One estimate was that fire planning had to be done 2 to 3 hours ahead of schedule to assure its completion in time. Another respondent complained of having to take the grids from the ELP printout and locate them on the map. Other problems included getting ammunition updates and troubleshooting.

Personnel were asked which tasks should be modified and how they should be modified. The major suggestions were to modify the fire planning programs and to provide the VFMED with a limited capability for generating its own formats.

Personnel were asked for suggestions for improving their performance as operators. One of the most common responses was to learn how to type. Other common responses included the following: "Put the keyboard in a more accessible space" (see the VFMED equipment evaluation), "Design the map board so it can be put in a convenient place to work with the VFMED," "Always have an assistant at the VFMED for reading ELP output," "More training," "Train the operators in the entire scope of functions," "Place some sort of stand or clipboard at the VFMED for keeping notes."

Personnel were asked to estimate the percentage of time they needed to consult technical manuals or other reference materials to perform their jobs. The median estimate was 17.5%. The following tasks were listed as the most frequent reasons for consulting reference material: message formats, legal entries, mnemonics, and unfamiliar tasks.

DMD Sites. The following responses were received for "On the average the tasks required of me in operating the TACFIRE equipment were."

A Very Easy	B Easy	C Borderline	D Difficult	E Very Difficult	N
38%	51%	10%	0%	0%	76

The overwhelming majority of the respondents regarded their tasks, on the whole, to be easy. When asked to list the tasks which caused them the most difficulty, the following problems were cited: communications, authentication, illumination missions, putting the external power cable to the mount of the M151A1 power system, registrations and special missions, and troubleshooting.

Respondents were asked to list the tasks that should be modified and to suggest how they should be modified; one suggestion was to modify illumination missions by allowing the FU to call in the illumination portion by voice and the grid portion via the DMD. Other recommendations were for more and better training and for better equipment.

Miscellaneous suggestions for improving their performance as operators included the following: "Provide a course to instruct DMD operators in maintenance, troubleshooting, operation, and in the performance of all types of missions with the DMD"; "Provide a second net for digital traffic"; "Train in realistic settings"; "Provide instruction in battalion shelter operations"; "Provide additional detailed information on operator's maintenance."

When personnel were asked to estimate the percentage of time they needed to consult technical manuals or other reference materials to perform their jobs, the median estimate was 10%. The manuals were consulted most frequently for troubleshooting and the looking up of mnemonics.

Training

The results of the training evaluation are presented in two parts. The first set of results represents the only individual performance assessments taken of the player personnel in OT 056. The second set of results were subjective assessments of TACFIRE training and of the training required to maintain TACFIRE operator skills.

Performance Assessments. Only two performance assessments were taken of individual operator proficiency. One assessment was taken of FDC personnel at the ACC in mid-November, 6 weeks after the second Fire Support Course had graduated from USAFAS. The other assessment was of DMD operators after they had completed their initial course of instruction.

The detailed results of ACCO performance are presented in Griffith, 1979. To summarize, the mean percentage errors were 14.93% for the June Fire Support Course and 12.1% for the September Fire Support Course. This difference was not significant statistically ($\alpha = .05$). Of the eight processing requirements timed, only one resulted in a statistically significant difference, and this difference was in favor of the

September class. As nearly as could be ascertained, the two classes were essentially equivalent with respect to ability (e.g., the course performance of the two groups did not differ statistically, and approximately the same proportion of each class could type). Given these conditions, the basic conclusion of the study was that individual operator proficiency levels off by the time operators have received 10 weeks of hands-on training following formal course training. This conclusion was restricted to individual operator proficiency in this study, however. It is not necessarily the case that team performance under operational conditions had also leveled off.

DMD operators had to take a performance test following their initial course of instruction. Of the 207 individuals who took the course, 47 (22%) failed the initial test. Nineteen of these individuals were retested, and 17 passed. The scores of individuals who passed and for whom scores were correctly recorded were summarized. The mean time for correctly processing fire mission was 533.14 seconds (N = 154, $SE_{\bar{X}}$ = 10.9). The average time for processing any one mission was 1 minute, 46 seconds. Note that the DMD course is intended only to provide the operator with an initial working knowledge of the device. Additional practice is necessary for the operator to become proficient.

Subjective Evaluations. TCATA questionnaires provided assessments of TACFIRE OT 056 training. Summaries of these questionnaires are provided in the TCATA report. According to the ARI questionnaires regarding operator performance and equipment evaluation, operators felt they needed more training on how to maintain and troubleshoot their equipment.

ARI questionnaires also addressed the issue of future training needs. Specifically, operators were asked to estimate (a) how frequently they needed to train to maintain proficiency with TACFIRE equipment and (b) how many days of training per year they needed to maintain proficiency with TACFIRE equipment. Answers (in percent) to the first question are summarized below, by operator group.

Operator group	A Daily	B Weekly	C Monthly	D Semi-annually	E Annually	N
FDC	14	64	18	0	3	28
VFMED	5	60	34	0	0	38
DMD	5	43	45	4	3	76

There is a strong consensus that training must be conducted frequently to maintain proficiency. A majority of FDC and VFMED personnel think that training must be conducted on a weekly basis, and 48% of DMD operators think that training should be conducted on a daily or weekly basis.

The second question concerned the total number of days training per year needed to maintain operator skills. Again, the results were analyzed by operator position. Twenty-six FDC personnel estimated the amount of training required to maintain their proficiency. The estimates ranged from 1 day a year to 365 days a year, with the median response being 105 days a year. Estimates provided by 37 personnel at VFMED sites ranged from 12 days a year to 300 days a year, with the median response of 90 days a year. Seventy-four DMD operators provided estimates ranging from 2 days a year to 365 days a year, with a median of 51 days a year.

In summary, operators think that a considerable amount of training at frequent intervals is required, or operator proficiency will suffer.

Personnel Selection

Given the small number of personnel involved in an operational test, only a preliminary assessment could be made of personnel selection requirements. Two sets of analyses are offered here; one is concerned with aptitude, the other with acquired skill. A series of analyses was done regarding the relationship between the aptitude area scores on the Army Classification Battery and success in formal TACFIRE training at Fort Sill, Okla. The second set of analyses was done on the relationship between typing skill and performance on the ACC.

Aptitude Area Scores and Success in Formal TACFIRE Training. Personnel records were obtained for 31 enlisted men who had successfully completed either the Fire Support Course or the Fire Support Coordination Course and for 18 enlisted men who had failed one of these courses. The means for each of these two groups for each of the aptitude areas and the associated statistics are presented in Table 8. With the exception of the OF comparison, all t values were significant at least at the .05 level of confidence. The statistic $\hat{\omega}^2$ provides an estimate of the magnitude of the effect; i.e., the greater the value, the greater the effect. On the basis of the obtained values, the SC and CO aptitude areas would seem to provide the best predictors for succeeding in TACFIRE schooling. However, given the small sample size, the reliability of these estimates is low. Additional study is required to establish a more reliable ordering.

An estimate of the potential utility of using aptitude area scores can be obtained by examining the obtained failure rates as a function of aptitude scores for the six areas which had the largest $\hat{\omega}^2$ values. For individuals with SC scores below 110, the failure rate was 64%. However, for individuals with SC scores 110 or above, the failure rate was 25%. For the CO aptitude area, the failure rate was 90% for individuals with aptitude scores below 110 versus 21% for individuals with CO scores of 110 or above. The values for

Table 8

Comparison on Aptitude Areas of Personnel Who Successfully Completed or Failed Formal TACFIRE Training

Aptitude area	Passed	Failed	Test statistic[a]	Magnitude estimate ($\hat{\omega}^2$)
GT	117	104	$t_{(47)}=3.42$	.179
GM	114	104	$t_{(47)}=3.09$	.148
EL	116	105	$t_{(47)}=3.62$	.198
CL	118	101	$t_{(47)}=3.28$	.202
MM	115	103	$t_{(47)}=3.70$	.205
SC	115	100	$t_{(27)}=3.53$	.283
CO	122	104	$t_{(37)}=3.93$	.270
FA	119	107	$t_{(27)}=3.04$	.221
OF	117	107	$t_{(28)}=1.51$	--
ST	117	106	$t_{(27)}=2.51$	.154

Note. GT = General Technical; GM = General Maintenance; EL = Electronics Repair; CL = Clerical; MM = Mechanical Maintenance; SC = Surveillance and Communications; CO = Combat; FA = Field Artillery; OF = Operational Food; ST = Skilled Technical

[a]The degrees of freedom vary as a function of the availability of individual aptitude area scores.

FA are 70% versus 32%; for EL, 58% versus 23%; and for GT, 65% versus 23%. These values are based only on enlisted personnel (ACB scores are not kept for officers) and are therefore conservative estimates. For example, if officers, all of whom have GT scores of at least 110, were to be included in the GT estimate provided above, the percentage of failures for 110 and above would drop below 10%. No officers failed to complete formal course training.

To summarize, failure rates can be drastically reduced by using a classification criterion from the ACB.

Typing Ability and ACCO Performance. A number of people had observed that the ability to type facilitated operator performance at the ACC. The validity of these observations was assessed by analyzing operational performance on the ACCO examination (see section on Training). Personnel were classified into two groups on the basis of their ability to type. Individuals who could type averaged 96 seconds per processing requirement, whereas individuals who could not type averaged 121 seconds. This difference was statistically significant, $t_{(17)} = 3.27$, $p \leq .01$. Moreover, the relative magnitude of the effect was large, $\hat{\omega}^2 = .377$.

Although the effect of typing ability on processing time was significant, the effect of typing ability on processing accuracy was not: $t_{(17)} = 1.14$, $p > .10$. Thus, typing ability enhances the speed at which messages are processed at the ACC, but has no significant effect on the accuracy of the messages processed. It is reasonable to assume that a similar relationship would be obtained at the VFMED.

CONCLUSIONS

The subjective assessment by the OT 056 players indicated that the battalion S-280 shelter is unacceptable. The major shortcomings are reported as unacceptable workspace and storage space. This space shortage is thought to adversely affect operations inside the shelter and the performance of maintenance. There is also dissatisfaction with the way equipments are configured. In addition, the noise level within the shelter is not regarded as acceptable by a majority of the respondents. Furthermore, there are indications that the noise level interferes with spoken communications within the shelter, and it is likely that the noise level contributes to operator fatigue. Noise levels exceeded standards in MIL-STD-1474A (see Appendix B).

Air quality within the shelter is questionable. Less than half the respondents regarded the air quality as acceptable, and, prior to OT III, personnel became ill within the shelter.

Finally, the dock of the shelter and the ladder constitute potential safety hazards. The DT III Human Factors Subtest[3] indicated that the battalion shelter was unsatisfactory, and OT III replicates this finding. If anything, the problems of the battalion shelter are intensified in an operational environment.

The DivArty shelters appeared to be satisfactory; however, the limited number of personnel involved at DivArty require that conclusions regarding the DivArty configuration be taken with caution. Noise levels exceeded MIL-STD-1474A (see Appendix B). The two shelter configurations did not appear to inhibit the adequate supervision of DivArty FDC operations. The suggestions offered for reconfiguring equipments at both DivArty and battalion should be given serious consideration.

Except for the DMD and the DPM, the overall acceptance rates for equipment surveyed exceeded 70%. A common complaint concerned the difficulty in troubleshooting and maintaining the DPM. Indeed, common problems for all TACFIRE equipments are troubleshooting and maintenance. In most cases, shortcomings in both maintainability design and in maintenance training contribute to this problem. On the whole, however, there is widespread acceptance of individual TACFIRE equipments. Nevertheless, the suggestions offered for equipment modification should be considered.

Regardless of their position, TACFIRE personnel perceive their tasks, on the average, as easy. Most suggestions regarding improvement in operating procedures at the battalion Fire Direction Center concerned the problem of equipment configuration (discussed above). The suggestions for improving operating procedures are discussed in the "Results" section and should be considered.

Although they perceive their tasks as easy, operators still think that frequent (weekly) training is needed to maintain proficiency. An experimental assessment of operator skill loss rates should be conducted. The kinds and amount of training that are required to maintain TACFIRE skills should be considered. The impact of training shortfalls on TACFIRE system performance could be devastating. It is likely that a variety of training approaches will be necessary to eliminate this problem.

The analyses of personnel selection requirements led to two basic conclusions. Operators who use the QWERTY keyboard should know how to type, and the Army Classification Battery has potential as a cost-effective selection device for formal TACFIRE schooling. Persons who can type show significantly greater facility at the keyboard. The

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[3] ARI report submitted to U.S. ARMTE, White Sands Missile Range, N. Mex., 19 October 1977.

analysis of ACB scores indicated that by using various aptitude areas, failure rates at school could be greatly reduced.

APPENDIX A

ARI TACFIRE QUESTIONNAIRES

TACFIRE HUMAN FACTORS EVALUATION

INSTRUCTIONS

This questionnaire is part of the Human Factors evaluation the Army Research Institute is conducting of the TACFIRE system. Your input to this evaluation will be invaluable in assisting us in making recommendations to improve the TACFIRE system. When multiple choice responses are provided mark the alternative that is closest to your opinion. When a written answer is requested be as detailed as you like in your response. Additional paper will be supplied if necessary. These data are to be used for research purposes only. Strict confidentiality will be maintained.

You should be able to answer the following questionnaires on the basis of your experience with TACFIRE. Should you be unable to answer certain items, please so indicate. You need only fill out the complete heading on the first questionnaire. Please provide at least your last name on each questionnaire, however, so the data can be collated should be questionnaire packet become separated.

You may detach this sheet. Any comments you wish to convey telephonically and/or anonymously should be addressed to Dr. Griffith, 532-9826/1316.

DATA REQUIRED BY THE PRIVACY ACT OF 1974
(5 U.S.C. 552a)

TITLE OF FORM	PRESCRIBING DIRECTIVE
	AR 70-1

1. AUTHORITY

10 USC Sec 4503

2. PRINCIPAL PURPOSE(S)

The data collected with the attached form are to be used to research purposes only.

3. ROUTINE USES

This is a collection form developed by the U.S. Army Research Institute for the Behavioral and Social Sciences pursuant to its research mission as prescribed in AR 70-1. When identifier (name or Social Security Number) are requested they are to be used for administrative and statistical control purposes only. Full confidentiality of the responses will be maintained in the processing of these data.

4. MANDATORY OR VOLUNTARY DISCLOSURE AND EFFECT ON INDIVIDUAL NOT PROVIDING INFORMATION

Your participation in this research is strictly voluntary. Individuals are encouraged to provide complete and accurate information in the interests of the research, but there will be no effect on individuals for not providing all or any part of the information. This notice may be detached from the rest of the form and retained by the individual if so desired.

FORM	Privacy Act Statement - 28 Sep 75

DA Form 4368-R, 1 May 75

PERSONNEL DATA FORM

1. Name: _____
Last First MI

*2. SSAN: _/_/_/-/_/_/-/_/_/_/_/ 3. Rank: _____

4. MOS: _____ 5. Test Position: _____

6. Weeks Experience in Test Position: _____

7. Did you receive TACFIRE training at Fort Sill?

Yes _____ No _____

If "yes", when was this training completed? _____

8. Height: _____ 9. Weight: _____
Ft - Inches lbs

10. Date of Birth _____ 11. Length of Service _____
Yrs - Months

12. Indicate whether you are right handed or left handed.

left _____ right _____

13. Can you type? Yes _____ No _____

If "yes," how many words per minute can you type? _____
wpm

14. Prior to your experience with TACFIRE, did you have any background or experience with computers?

Yes _____ No _____

If "yes", what was the nature of this experience?

*You are not required to supply this item of information

15. List your military job experience.

16. List your military school experience.

17. List your civilian job experience.

18. Civilian education? _____ yrs.

List your civilian educational experience.

NAME: _____ RANK: _____

TACFIRE DUTY POSITION: _____ UNIT: _____

OPERATOR'S QUESTIONNAIRE

1. How frequently do you have to train to maintain your proficiency with your TACFIRE equipment? (Provide your best estimate.)

A	B	C	D	E
Daily	Weekly	Monthly	Semi-Annually	Annually

2. How many days per year of training do you require to maintain your proficiency with your TACFIRE equipment? (Provide your best estimate.)

_____ days year

3. Approximately what percentage of the time did the technical manuals or other reference materials have to be consulted to perform your job?

_____ percent

4. For which tasks did the technical manuals or other reference materials have to be consulted most frequently?

5. On the average the tasks required of me in operating the TACFIRE equipment were:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

6. Which tasks caused you the most difficulty?

7. Which tasks should be modified and how should they be modified?

8. Use the space below to provide any suggestions you might have for improving your performance as an operator.

Name: _____ Rank: _____

Duty Position: _____ Unit: _____

SAFETY QUESTIONNAIRE

1. Use the space below to describe any hazards or potential hazards you noticed with respect to the TACFIRE equipment.

2. Use the space below to provide any suggestions you might have for making the TACFIRE system safer to operate and maintain.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

TEAM PERFORMANCE

1. What modifications, if any, in the design of the equipment would improve the teamwork of the crew?

2. What modifications, if any, in the operating procedures would improve the teamwork of the crew?

3. Please provide any other comments or suggestions concerning equipment design or operating procedures.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

WORKLOAD

1. What percentage of the time did your workload become so heavy that, in your opinion, your performance suffered? _____ %

When, specifically, did your workload become overly heavy?

2. What percentage of the time was your workload so light that you could have provided assistance to another member of the crew? _____%

When, specifically, would you have been able to assist other team members?

3. Use the space below to provide any recommendations you might have redistributing the workload to achieve more efficiency.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

SHELTER ENVIRONMENT QUESTIONNAIRE

1. Overall, the shelter environment was:

A	B	C	D	E
Very Comfortable	Comfortable	Borderline	Uncomfortable	Very Uncomfortable

2. Typically, the temperature in the shelter was:

A	B	C	D	E
Much Too Hot	Too Hot	About Right	Too Cold	Much Too Cold

3. The temperature control system in the shelter was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

4. The quality of the air was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

5. The work space provided in the shelter was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

6. The storage space provided was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

7. The working surface was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

8. The level of illumination in the shelter was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

9. The noise level in the shelter was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

10. Spoken communications within the shelter were:

A	B	C	D	E
Very Easy to Understand	Easy to Understand	Borderline	Difficult to Understand	Very Difficult to Understand

11. The chairs were:

A	B	C	D	E
Very Comfortable	Comfortable	Borderline	Uncomfortable	Very Uncomfortable

12. Working conditions inside the shelter were:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

13. Working conditions inside and outside the shelter were:

A	B	C	D	E
Very Safe	Safe	Borderline	Dangerous	Very Dangerous

Use the space below to provide comments about your answers to the above items as well as to provide any suggestions you might have for improving conditions within the shelter.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

ARTILLERY CONTROL CONSOLE (ACC)

1. The overall performance of the ACC was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

2. The design of the keyboard on the ACC was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

3. The design of the controls on the ACC was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

4. The design of the receive display editor was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

5. The design of the compose/edit display editor was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

6. The design of the ACC for ease of message composition was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

7. The design of the ACC for ease of message correction was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

8. The design of the ACC for ease of reviewing messages was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

9. Troubleshooting the ACC was:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

Use the space below (and the back, if necessary) to discuss any problems you had with the ACC and to provide any suggestions you might have for improving the ACC.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

CENTRAL COMMUNICATIONS UNIT (CCU)

1. Overall, the performance of the CCU was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

2. The design of the controls on the CCU was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

3. Troubleshooting the CCU was:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

Use the space below (and the back, if necessary) to discuss any problems you might have had with the CCU, and to provide any suggestions you might have for improving the CCU.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

DIGITAL PLOTTER MAP (DPM)

1. Overall, the performance of the DPM was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

2. The design of the controls on the DPM was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

3. The DPM was:

A	B	C	D	E
Highly Legible	Legible	Borderline	Illegible	Highly Illegible

4. Troubleshooting the DPM was:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

Use the space below (and the back, if necessary) to discuss any problems you might have had with the DPM, and to provide any suggestions you might have for improving the DPM.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

ELECTRONIC LINE PRINTER (ELP)

1. Overall, the performance of the ELP was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

2. The design of the controls on the ELP was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

3. The design of the ELP for ease of reviewing messages was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

4. The ELP printouts were:

A	B	C	D	E
Highly Legible	Legible	Borderline	Illegible	Highly Illegible

5. Troubleshooting the ELP was:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

Use the space below (and the back, if necessary) to discuss any problems you might have had with the ELP, and to provide any suggestions you might have for improving the ELP.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

VARIABLE FORMAT MESSAGE ENTRY DEVICE (VFMED)

1. Compared to the transmission of messages using a radio, the entry and transmission of messages with the VFMED was:

A	B	C	D	E
Much Better	Better	The Same	Worse	Much Worse

2. As my means of interfacing with the TACFIRE system, the VFMED was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

3. The design of the keyboard on the VFMED was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

4. The design of the display on the VFMED was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

5. The design of the controls on the VFMED was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

6. Troubleshooting the VFMED was:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

7. The design of the VFMED for ease of message composition was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

8. The design of the VFMED for ease of message correction was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

9. The design of the VFMED for ease of reviewing messages was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

Use the space below (and the back, if necessary) to discuss problems you had with the VFMED and to provide any suggestions you might have for improving the VFMED.

Name: _____ Rank: _____

TACFIRE Duty Position: _____ Unit: _____

DIGITAL MESSAGE DEVICE (DMD)

1. Compared to the transmission of messages using a radio, the entry and transmission of messages with a DMD was:

A	B	C	D	E
Much Better	Better	The Same	Worse	Much Worse

2. As the Forward Observer's means of interfacing with the TACFIRE system, the DMD was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

3. The design of the Keyboard on the DMD was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

4. The design of the display on the DMD was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

5. The design of the controls on the DMD was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

6. Battery replacement was:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

7. Troubleshooting the DMD was:

A	B	C	D	E
Very Easy	Easy	Borderline	Difficult	Very Difficult

8. The design of the DMD for ease of message composition was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

9. The design of the DMD for ease of message correction was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

10. The design of the DMD for ease of reviewing messages was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

11. The design of the DMD for night operation was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

12. The design of the DMD for acknowledging ACK/NAK was:

A	B	C	D	E
Very Acceptable	Acceptable	Borderline	Unacceptable	Very Unacceptable

Use the space below (and the back, if necessary) to discuss any problems you might have had with the DMD and to provide any suggestions you might have for improving the DMD.

Appendix B

Noise Level Survey

DEPARTMENT OF THE ARMY
HEADQUARTERS III CORPS AND FORT HOOD
FORT HOOD, TEXAS 76544

AFZF-DMA-HE

21 March 1978

SUBJECT: Results of a Noise Level Survey in TACFIRE

1. References:

a. AR 40-5, 25 Sep 74.

b. TB MED 251, 7 Mar 72.

c. MIL-STD 1474-A, 1 Mar 73.

2. Background.

a. A request for a noise level survey was received by 1LT Pengelly, Hearing Conservation Officer, Health and Environment Activity, US Darnell Army Hospital from Douglas Griffith, Ph. D., Army Research Institute, Ft. Hood Field Unit. Dr. Griffith received numerous complaints from personnel working in TACFIRE shelters. The subjective remarks included complaints of difficulty with conversation and high noise levels.

b. TACFIRE shelters are mounted on 812 series trucks (5 ton). Power for electronic equipment is provided by 15KW generators which are positioned to meet tactical needs. The distance of the generators from the shelters can vary from 10 to 50 meters. The power source for the Battalion shelter was commercial AC current and three 15KW generators for the Divisional Shelters.

c. The survey of the Battalion shelter was conducted on 7 Feb 78 at the ARTADS site, Ft. Hood. Measurements of the Divisional shelters was conducted on 22 Feb 78 in a tactical configuration near Engineer Lake, Ft. Hood, TX.

TABLE I

Test Conditions Battalion Shelter

1. Air conditioner on low evaporator speed, all equipment operating with ELP printing and DPM plotting.

2. Air conditioner on high evaporator fan speed, equipment operating as per #1 above.

3. Equipment as per #1, heater on high evaporator speed.

4. Equipment as per #1, heater on low evaporator speed.

NOISE LEVELS AT ARTILLERY CONTROL CONSOLE

Ambient Level 65 dB(A)

Test Condition	1	2	3	4	
Operator's Position	70	74	74	65	dB(A)
Octave Band					
125 Hz	72	74	73	72	dB
250 Hz	66	79	78	65	
500 Hz	63	72	73	62	
1000 Hz	67	67	65	61	
2000 Hz	60	62	64	58	
4000 Hz	66	61	61	58	
8000 Hz	46	51	55	44	

NOISE LEVELS AT COMMUNICATIONS CONTROL UNIT

Ambient Level 65 dB(A)

Test Condition	1	2	3	4	
Operator's Position	73	74	76	65	dB(A)
Octave Band					
125 Hz	73	78	76	70	dB
250 Hz	70	80	80	66	
500 Hz	65	76	73	67	
1000 Hz	59	66	68	58	
2000 Hz	66	64	64	59	
4000 Hz	57	59	61	57	
8000 Hz	45	56	63	43	

TABLE II

Test Conditions Display Shelter

1. Air conditioner on low evaporator speed, all equipment operating with ELP printing and DPM plotting.

2. Air conditioner on high evaporator speed, equipment operating as per #1.

3. Equipment as per #1, heater on high evaporator speed.

4. Equipment as per #1, heater on low evaporator speed.

DIV ARTY SHELTERS

Display Shelter

Artillery Control Console (ACC)

Ambient Level 65 dB(A)

Test Condition	1	2	3	4	
Operator's Position	72	76	80	67	dB(A)
Octave Band					
125 Hz	73	75	79	66	dB
250 Hz	68	80	80	64	
500 Hz	62	73	77	63	
1000 Hz	66	69	76	70	
2000 Hz	62	63	73	58	
4000 Hz	64	64	68	55	
8000 Hz	53	58	65	47	

TABLE III

Test Conditions Computer Shelter

1. Air conditioner on low evaporator fan, CCU operating.

2. Air conditioner on high speed evaporator fan, on equipment as per #1.

3. Heater on low evaporator fan speed, equipment as per #1.

4. Heater on high evaporator fan speed, equipment as per #1.

Computer Shelter

Communications Control Console (CCU)

Ambient Level 66 dB(A)

Test Condition	1	2	3	4	
Operator's Position	73	77	63	79	dB(A)
Octave Band					
125 Hz	74	79	61	80	dB
250 Hz	72	74	62	79	
500 Hz	69	72	62	76	
1000 Hz	67	72	58	76	
2000 Hz	62	63	59	65	
4000 Hz	54	59	45	60	
8000 Hz	52	54	41	56	

TABLE IV

Test Conditions Counterfire Van

1. Air conditioner on low evaporator speed, VFMED operating.

2. Air conditioner on high evaporator fan speed, equipment as per #1.

3. Equipment as per #1, heater on high fan speed.

4. Equipment on #1, heater on low fan speed.

Counterfire Van

Variable Format Message Entry Device (VFMED)

Ambient Level 63 dB(A)

Test Condition	1	2	3	4	
Operator's Position	72	77	76	67	dB(A)
Octave Band					
125 Hz	56	54	56	58	dB
250 Hz	63	65	61	61	
500 Hz	64	68	63	63	
1000 Hz	68	71	70	68	
2000 Hz	71	75	73	71	
4000 Hz	65	63	64	61	
8000 Hz	61	59	57	54	

TABLE V

Test Conditions Digital Message Device (DMD)

The DMD was connected to a RT524/VRIC field radio mounted on a Truck, 1/4 Ton, 4'x4' M151AZ (jeep). The DMD was connected to the radio by the retransmit jack. Measurements were made with the speaker off (using only the handset) and speaker on. Volume was set at one-third. This volume was described by CW2 Lloyd, TACFIRE Maintenance Technician, Headquarters, Divisional Artillery 1st Cav, as a setting typical of those used under tactical field conditions.

Sound level measurements were obtained in a flat open grass-covered field with no structures closer than 200 feet. Wind speed was 5 mph and a three inch wind screen was used. The test was conducted on 31 March 1978 at 0600 hours.

Digital Message Device

Ambient Noise Level 54 dB(A)

Hand Set - 1/3 volume

Distance from Noise Source-1-1/4	2	6	Meters
A weighting	70	67	56 dB(A)
63 Hz	54	51	49 dB
125 Hz	56	53	52
250 Hz	58	56	53
500 Hz	63	58	53
1000 Hz	64	62	55
2000 Hz	70	68	56
4000 Hz	59	65	53
8000 Hz	54	58	51

Speaker - 1/3 volume

Ambient Noise Level 54 dB(A)

Distance from Noise Source-1-1/4	2	6	10	Meters
A weighting	79	76	69	55 dB(A)
63 Hz	54	51	48	49 dB
125 Hz	60	54	53	54
250 Hz	62	59	56	51
500 Hz	69	63	61	53
1000 Hz	74	68	67	54
2000 Hz	79	75	70	58
4000 Hz	72	71	63	53
8000 Hz	66	65	62	55

CONCLUSIONS

1. The primary sources of noise within the TACFIRE shelters are the Heater/Air Conditioner, Digital Plotter Map, and Electronic Line Printer.

2. The noise levels obtained in this survey do not pose a hazard to hearing.

3. Noise levels obtained within the Battalion Shelter exceed MIL STD 1474A, category F from 5-9dB at the ACC and CCU operator's position.[1]

4. Noise levels obtained within the Divisional Computer Shelter exceed MIL STD 1474A, category F from 8-15dB at the CCU operator's position. Levels obtained with the heater on low evaporator fan speed are within acceptable limits.

5. Noise levels obtained within the Counterfire Van exceed MIL STD 1474A from 6 to 12 dB. Levels obtained with the heater on low evaporator fan speed are within acceptable limits.

6. Noise levels which exceed levels for category F also exceed alternate PSIL-4 criteria. (Preferred Speech Interference Level PSIL-4, is the arithmetic mean of the octave band frequencies of 500, 1000, 2000, and 4000 Hz.

7. Standards for aural non-detectability were not specified by the procuring activity. Octave band levels obtained from the Digital Message Device exceeded levels for aural non-detectability for 30 meters for the handset and 200 meters for the speaker. Determination of non-detectability for distances greater than 200 meters was not possible due to the ambient noise level.

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[1]Noise levels observed to exceed category F and PSIL-4 criteria will reduce speed intelligibility and interfere with telephone communication.

RECOMMENDATIONS

1. The Air Conditioner/Heater, Digital Plotter Map, and Electronic Line Printer appear to be the primary sources of noise within the TACFIRE system. Consideration should be given to modification or replacement of this equipment to reduce noise levels.

2. A requirement for non-detectability should be specified for the Digital Message Device.

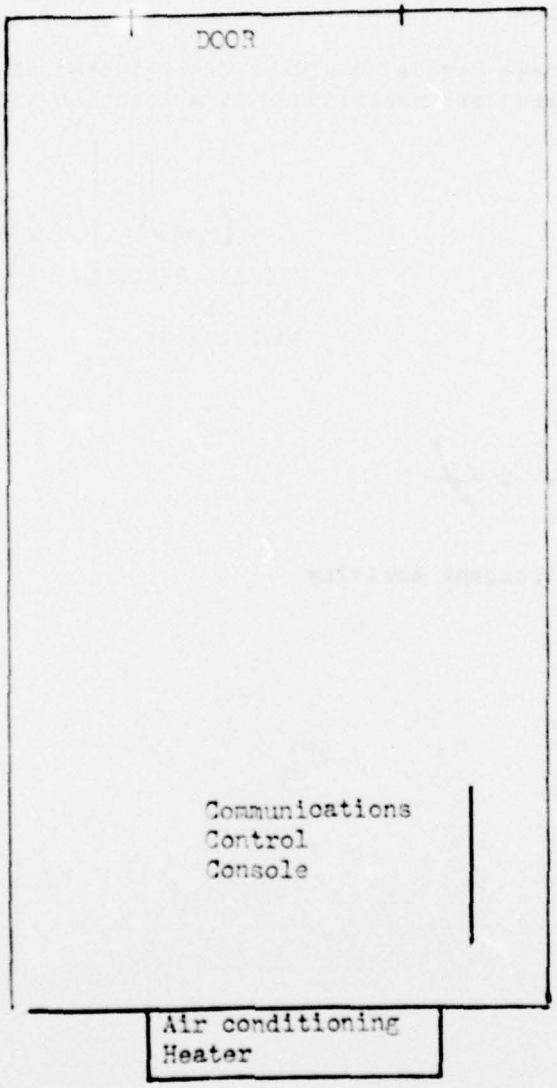
3. The Digital Message Device should be re-evaluated after non-detectability standards are established at a location with a lower Ambient Noise Level.

MICHAEL PENGELLY
1LT, MSC
Audiologist

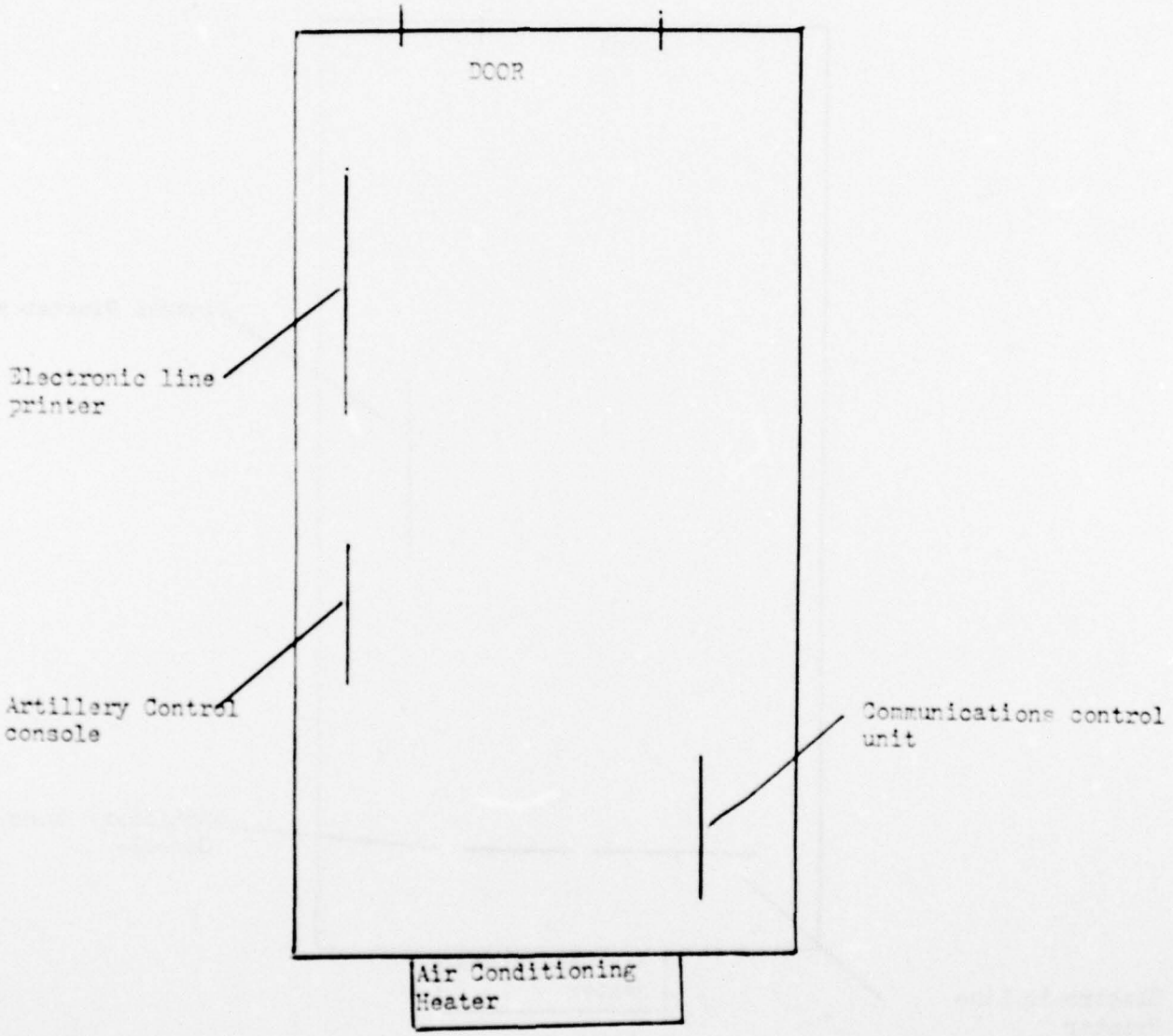
Approved

ARTHUR R. MORTON, JR.
LTC, MC
Chief, Health & Environment Activity

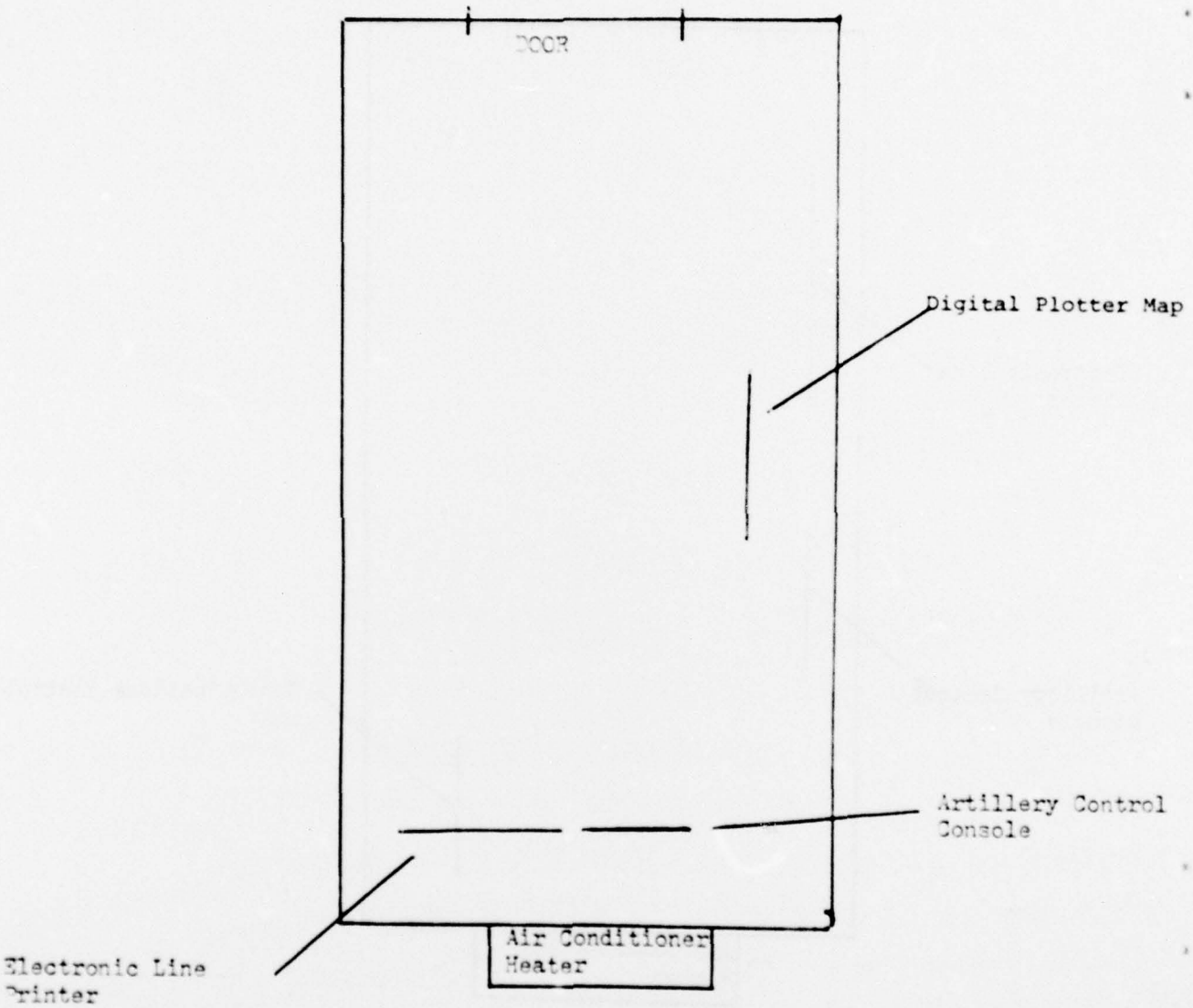
Appendix I Drawing D
Computor Shelter



Appendix I Drawing A
Battalion Shelter



Appendix I Drawing B
Display Shelter



Appendix I Drawing C
Counterfire Van